# ASSESSMENT OF FOOT ARCH SHAPE AND HEALTH STATUS OF ADULT POPULATION FROM EASTERN SLOVAKIA

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**SUMMARY**

*Background:* The purpose of this study was to determine the foot arch shape and the associated health status in a selected sample of individuals belonging to the adult majority population of eastern Slovakia and to evaluate which of the observed factors are involved in the occurrence and development of foot arch abnormalities.

*Methods:* The weight and height of probands were measured according to standard anthropometric methods using a personal scale and an anthropometer. The BMI index was calculated for each proband from the measured data. A Pod4Foot Classic podoscope was used to obtain the plantograms. The Chippaux-Smirak index method was used to evaluate the plantograms. The study includes a questionnaire containing questions about factors affecting the foot arch shape.

*Results:* The arch of the right foot was supported by the effect of wearing shoes at home ($p = 0.013$). There was an association between wearing high-heeled shoes and foot arch disorder, both on the right ($p = 0.011$) and left ($p = 0.045$) foot. There was no significant relationship between the prevalence of overweight or obesity, between wearing orthopaedic insoles in shoes without a prescription, wearing orthopaedic footwear at home, between sport or static and active work and foot arch disorder in our study.

*Conclusions:* Most of the probands had a bilaterally normal arched foot, which is a positive result. Nowadays, there are a large number of orthopaedic devices on the market that help to shape the arch of the foot properly, but it is not correct to use these devices arbitrarily, without a doctor's prescription and a diagnosis of foot arch deviation.

*Key words:* foot arch, plantography, Chippaux-Smirak index, podoscope

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## INTRODUCTION

In the process of evolution, the human foot had to constantly adapt to the needs of man, until it has become one of the most complex structures of the human body, which performs important functions. In addition to its static function, the human foot, thanks to its proprioceptors and contact with various surfaces, helps to adapt the other segments of the lower limb as well as the whole body to its current position and movement. The correct function of the proprioceptors is directly related to the condition of the arch of the foot. Disorders of the arch of the foot have an impact on changes in the postural, stability, as well as motoric skills of a person.

The occurrence of abnormalities in the arch of the foot is the second most common health problem that can lead to pathological processes affecting the functionality of the foot. Untreated foot arch disorders can be the source of functional and later structural changes anywhere in the musculoskeletal system. Foot arch disorders often lead to a reduction of human life quality and are associated with chronic pain and diseases of other lower limb segments or the spine. The pathological change in the periphery can extend through the muscle chains to the knee and hip joints and through the pelvis to the spine, head, and shoulders (1, 2). A decrease in foot arch leads to an increase in internal rotation of the hip joints (3).

It is important to pay attention to a lifestyle, wear the right footwear, and avoid factors that can negatively affect the arch of the foot already in childhood. There are several procedures currently available for early diagnosis of foot arch disorders. Plantography is an effective, adequate, and accurate method. Plantogram is an image of the foot arch which also shows the metatarsal and the heel part of the foot and the toes. By measuring the selected parameters and calculating the indices, it is possible to determine the condition of the foot arch. The deviation is considered to be a flat foot, where the arch is fallen, and a hollow foot or high arch, where the longitudinal arch of the foot is abnormally elevated

(4). Arch disorders may also be closely related to deformities of the toes and big toe.

The purpose of this study was to determine the foot arch shape and the associated health status in a selected sample of individuals belonging to the adult majority population of eastern Slovakia and to collect basic information about the probands' physical activities, work performed, preferred footwear, and other relevant information affecting the shape of the foot arch. According to the obtained information, attention focused on the evaluation, which of the observed factors are involved in the development of deviations of the foot arch.

## MATERIALS AND METHODS

In this study, a total of 72 probands were enrolled aged from twenty to fifty years. All probands were from the Prešov and Košice regions in eastern Slovakia and belonged to the majority population. Probands included in the research had diagnosed no foot/lower limb disorder and/or gait, also were without major surgical interventions related to the lower limb at the time of measurement. Probands were without previous fractures of the foot or lower limb bones. All probands were at least 18 years of age, which is suitable for the examinations, as growth changes in the foot are complete at 17 years of age in both sexes. The footprints were taken from volunteers at the Department of Biology at the University of Prešov and from employees and volunteers of the Slovak Red Cross, Territorial Association of Košice and Prešov. Each person involved in the study was informed about all the details of the ongoing study and participated voluntarily. The study includes a questionnaire containing questions focused on whether the probands wore non-prescription orthopaedic insoles in shoes, whether women wore high-heeled shoes, whether the probands wore any type of footwear or orthopaedic shoes at home, and what kind of work, sport, or physical activity they do.

Body weight and body height were measured for each proband by standard anthropometric methods using a personal scale and an anthropometer (5). From these data, the body mass index (BMI) was calculated for each proband. BMI was assessed according to the following scale: underweight (less than 18.5 kg/m$^2$), normal weight (18.5–24.9 kg/m$^2$), overweight (25–29.9 kg/m$^2$), and obesity (30 kg/m$^2$ or more) (6).

A Pod4Foot Classic podoscope was used to obtain the plantograms. An image of the foot was captured by podoscope and subsequently analysed. The backlighting of podoscope was turquoise, orange or white light, depending on the lighting conditions in the room. The backlighting allowed monitored different high pressures on different parts of the foot. We focused on a static assessment, the subject stood barefoot on the glass podoscope stage. We did not take images in which the footstep was monitored over the toe, heel, or squatting position of the feet. The image of the foot was taken using an appropriate compatible program. The Chippaux-Smirak index method was used to evaluate the plantograms. Based on the results, according to the percentage range, the type of foot was determined as normal foot, flat foot (fallen arch), or hollow foot (high arch) (7).

The statistical software Statistica 13.5 was used for data processing. The Pearson correlation coefficients were calculated to determine the relationship between values of the Chippaux-Smirak index and BMI. The association between the condition of the foot arch and selected factors was detected by chi-squared test. P-value $< 0.05$ was considered statistically significant.

## RESULTS

In this study, a total of 72 probands were enrolled, 47 (65.3%) were females and 25 (34.7%) were males. The average age of the probands was 28.3 (SD = 5.7) years, 27.5 (SD = 5.1) years for females, and 29.8 (SD = 6.4) years for males. The average values of body height, body weight, and calculated BMI index can be seen in Table 1. The average BMI value in the study was 22.9 kg/m$^2$, so the majority of probands had a normal weight (Fig. 1). Underweight was found in 3 (4.2%) females, overweight in 9 (12.5%) females and 6 (8.3%) males, and obesity in 1 (1.4%) male.

Both right and left footprints of 72 probands were taken on the podoscope, resulting in a total set of 144 footprints. In females, deviation from the normal arched foot was found on the right foot in 11 (23.4%) cases and on the left foot in 9 (19.2%) cases. In males, the deviation was observed on the right foot in 3 (12.0%)

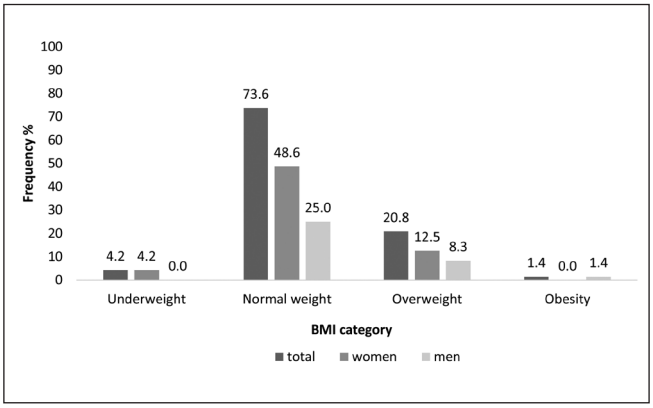


***Fig. 1.*** *BMI distribution in relation to gender.*

***Table 1.*** *Average values of anthropological parameters (N = 72)*

| | Total<br>Mean (SD) | Females<br>n = 47<br>Mean (SD) | Males<br>n = 25<br>Mean (SD) |
|---|---|---|---|
| Height (cm) | 174.7 (8.6) | 170.7 (6.7) | 182.2 (6.5) |
| Weight (kg) | 69.9 (11.2) | 64.9 (9.9) | 79.3 (6.3) |
| BMI (kg/m$^2$) | 22.9 (3.1) | 22.3 (3.2) | 23.9 (2.6) |

BMI – body mass index

***Table 2.*** *Evaluation of plantograms by gender*

| Degree of foot arch | | Females n = 47 | | Males n = 25 | |
|---|---|---|---|---|---|
| | | Right foot n (%) | Left foot n (%) | Right foot n (%) | Left foot n (%) |
| Normal foot | 1st | 4 (8.5) | 8 (17.0) | 4 (16.0) | 5 (20.0) |
| | 2nd | 26 (55.3) | 27 (57.5) | 15 (60.0) | 12 (48.0) |
| | 3rd | 6 (12.8) | 3 (6.4) | 3 (12.0) | 5 (20.0) |
| Flat foot (fallen arch) | 1st | 2 (4.3) | 0 (0.0) | 0 (0.0) | 0 (0.0) |
| | 2nd | 0 (0.0) | 0 (0.0) | 1 (4.0) | 0 (0.0) |
| | 3rd | 0 (0.0) | 1 (2.1) | 0 (0.0) | 1 (4.0) |
| Hollow foot (high arch) | 1st | 5 (10.6) | 3 (6.4) | 0 (0.0) | 0 (0.0) |
| | 2nd | 3 (6.4) | 3 (6.4) | 1 (4.0) | 1 (4.0) |
| | 3rd | 1 (2.1) | 2 (4.3) | 1 (4.0) | 1 (4.0) |

***Table 3.*** *Correlation between the value of Chippaux-Smirak index and BMI regardless of gender*

| | Right foot | | Left foot | |
|---|---|---|---|---|
| | r | p-value | r | p-value |
| BMI | −0.1969 | 0.097 | −0.1741 | 0.934 |

r – correlation coefficient; BMI – body mass index

cases and on the left foot also in 3 (12.0%) cases. Details about the foot arch types recorded are given in Table 2.

Since a majority of the probands were categorized as normal weight, and overweight or obesity was recorded in only 16 (22.2%) probands irrespective of gender, there was no significant relationship between the prevalence of overweight or obesity and foot arch disorder in the study (Table 3).

It was observed that 13 (18.1%) probands irrespective of gender wore orthopaedic insoles in shoes without a prescription. We did not observe a statistically significant relationship between wearing orthopaedic insoles in shoes without a prescription and the high arch foot (Table 4). Wearing non-prescribed orthopaedic insoles in shoes did not result in an increased right foot arch ($p = 0.182$) or left foot arch ($p = 0.476$).

It was observed that 53 (73.6%) probands regularly went barefoot at home. The remaining 19 (26.4%) probands wore some type of footwear at home. These were 14 (73.7%) females and 5 (26.3%) males. The relationship between wearing footwear

***Table 4.*** *Association between foot arch condition and effect of selected factors regardless of gender*

| | Right foot | | | | Left foot | | | |
|---|---|---|---|---|---|---|---|---|
| | Normal foot n (%) | Flat foot n (%) | Hollow foot n (%) | p-value | Normal foot n (%) | Flat foot n (%) | Hollow foot n (%) | p-value |
| WOI | 9 (12.5) | 0 (0.0) | 4 (5.5) | 0.182 | 10 (13.9) | 0 (0.0) | 3 (4.2) | 0.476 |
| nWOI | 49 (68.1) | 3 (4.2) | 7 (9.7) | | 50 (69.4) | 2 (2.8) | 7 (9.7) | |
| WFH | 11 (15.3) | 2 (2.8) | 6 (8.3) | **0.013** | 15 (20.8) | 0 (0.0) | 4 (5.5) | 0.421 |
| nWFH | 47 (65.3) | 1 (1.4) | 5 (6.9) | | 45 (62.6) | 2 (2.8) | 6 (8.3) | |
| WOF | 6 (8.3) | 1 (1.4) | 3 (4.2) | 0.201 | 8 (11.1) | 0 (0.0) | 2 (2.8) | 0.722 |
| nWOF | 52 (72.2) | 2 (2.8) | 8 (11.1) | | 52 (72.2) | 2 (2.8) | 8 (11.1) | |
| AS | 25 (34.7) | 1 (1.4) | 7 (9.7) | 0.413 | 27 (37.5) | 0 (0.0) | 6 (8.3) | 0.284 |
| nAS | 33 (45.9) | 2 (2.8) | 4 (5.5) | | 33 (45.9) | 2 (2.8) | 4 (5.5) | |
| SW | 6 (16.7) | 0 (0.0) | 1 (2.8) | 0.155 | 7 (19.4) | 0 (0.0) | 0 (0.0) | 0.069 |
| AW | 25 (69.4) | 0 (0.0) | 4 (11.1) | | 23 (63.9) | 0 (0.0) | 6 (16.7) | |
| WHH* | 6 (12.8) | 2 (4.3) | 1 (2.1) | **0.011** | 8 (17.0) | 1 (2.1) | 0 (0.0) | **0.045** |
| nWHH* | 30 (63.8) | 0 (0.0) | 8 (17.0) | | 30 (63.8) | 0 (0.0) | 8 (17.0) | |

WOI – wearing orthopaedic insoles in shoes without prescription; nWOI – not wearing orthopaedic insoles in shoes without prescription; WFH – wearing footwear at home; nWFH – not wearing footwear at home; WOF – wearing orthopedic footwear at home; nWOF – not wearing orthopaedic footwear at home; AS – active sports; nAS – not active sports; SW – static work; AW – active work; WHH – wearing high heeled shoes; nWHH – not wearing high heeled shoes; *only in females.
Numbers in bold indicate statistically significant values.

at home and foot arch status was statistically significant for the right foot (Table 4). The arch of the right foot was supported by the effect of wearing shoes at home ($p=0.013$). The left foot did not show a significant relationship ($p=0.421$).

Then, we focused our attention on the type of footwear at home. Orthopaedic shoes in the form of cork shoes with arch support or clogs with raised arches were worn by 10 (52.6%) probands and soft slipper shoes without arch support were worn by 9 (47.4%) probands. The relationship between wearing orthopaedic footwear at home and foot arch status was not statistically significant for the right foot ($p=0.201$) or left foot ($p=0.722$) (Table 4). Wearing orthopaedic shoes at home had no effect on the maintenance of a normal foot arch.

We also observed in probands the effect of some sport or physical activity, as well as the work (static and active work) on the occurrence of foot arch abnormalities, but we did not record a statistically significant association.

In the sample studied, 25 (53.2%) women reported wearing high-heeled shoes. However, 14 (29.8%) females wore high-heeled shoes only a few times a month and 2 (4.3%) females wore high-heeled shoes only a few times per year. Only 9 (19.2%) women of the total number wore high-heeled shoes regularly; 7 (14.9%) females a few times a week, and only 2 (4.3%) women wore high-heeled shoes every day. There was found association between wearing high-heeled shoes and foot arch disorder, both on the right ($p=0.011$) and left ($p=0.045$) foot (Table 4).

## DISCUSSION

In our study, we evaluated foot arching in the adult population, estimated health risks resulting from the recorded foot arch condition in probands, as well as various factors that influence the shape of the foot arch. We assessed the quality of the foot arch using the Chippaux-Smirak index method. If we want to capture the high foot and assume the occurrence of a high foot arch, it is recommended to use just this index according to the Chippaux-Smirak method (8).

In our study, the normally arched foot had the highest representation, which was identified in 118 (81.9%) footprints. Almost identical results were reported in Uhrová et al. research, where the representation of the normally arched foot was 82.1% (9). Shtin Baňárová recorded the prevalence of normally arched foot in only 51.6% of 122 probands (10). A lower percentage of the normal arched feet (54.5%) was reported in Son et al. research (11). Also, Gonzalez-Martin et al. found only 50.0% of normal arched feet in a sample of 835 probands (12). The differences can be attributed to the age mean, which was significantly higher in the compared studies, and also all the mentioned researches had a higher number of probands, compared to our research.

The prevalence of flat foot was only 3.5% in our sample. The most similar values are reported in Son et al. research, where the flat foot was 6.8% (11). The low prevalence of flat foot in our study may have been due to the smaller sample, as well as the fact, that we categorized most of the probands as normal weight by BMI index. The high foot was represented in 14.6% of our sample. The prevalence of high foot in our sample was more frequent in females, which was also recorded in Uhrová et al. research, where the high foot was recorded in 5.0% of females and only in 1.9% of males (9).

Obesity is one of the most serious factors influencing the development of several diseases and is also closely linked to foot arch disorders and the development of the flat foot. Obesity is often considered to be a factor that directly affects plantarflexion, foot position, and pronation, and equally affects the force of the pressure that is exerted on the foot and its components during walking. Our hypothesis that being overweight and obese would influence the incidence of flat feet was not statistically confirmed. The incidence of the flat foot did not increase with increasing BMI index. The BMI is calculated from the body weight and height of the proband but does not consider the overall composition of the human body. So, the data on the relationship between BMI and flat foot may be biased. The hypothesis about the link between being overweight and obese and the prevalence of flat foot has been the subject of many studies, but it is still not possible to confirm or refute it (9, 13–16).

Kandová states that one way to influence the foot arch is the use of orthotic insoles (13). Effective orthotic insoles are designed to support the foot arch on the medial side by elevating it at the sustentaculum tali and the articulatio talonavicularis. However, individuals who wear orthotic insoles without a prescription or diagnosis of flat foot may artificially support to elevating the foot arch and creating a high foot. Wearing orthotic insoles without a prescription is not beneficial for ensuring correct posture or locomotion generally. But in our study, this fact was not confirmed and wearing non-prescribed orthotic insoles did not caused an increase in the foot arch in probands. The reason for this may have been that only 13 (18.1%) probands in our study irrespective of gender wore orthopaedic insoles in shoes without a prescription.

Many shoe manufacturers are already trying to shape the bottom surface of the shoe itself so that it partially describes the arch, supports it, and shapes it. However, we are not talking about orthotic footwear or the use of orthotic insoles. There are also shoes with completely flat soles, called the flip-flops. Fuchsová et al. in their research state that up to 87.5% of women who wear flip-flops have a flat foot (17). Kokavec and Huraj have also commented on this issue, explaining how flat feet develop by wearing this type of footwear (18). The cause is a flat surface on which the foot slides, thus steps are shortened, and the body is subjected to exertion. Toe deformities are also a common consequence. The opposite of wearing flip-flops in women is wearing high-heeled shoes, which is also one of the factors affecting the foot arch; 25 (34.7%) women reported wearing high-heeled shoes, in our study. However, the relationship between wearing high heels and foot arch disorder was not statistically significant in our study. Similar results were reported by Fuchsová et al., where 18 (31.6%) of the 35 women studied wore heeled shoes, and none of these women were diagnosed with a foot arch disorder (17). However, we can conclude that the frequency of wearing heels itself is a factor. When we considered only women who wear high-heeled shoes every day or a few times a week, the association with foot arch disorder was demonstrated on both the right and the left foot.

There was a positive relationship between wearing shoes at home and a normal foot arch ($p=0.013$) on the right foot. We also investigated the effect of continuously supporting the foot arch with orthotic footwear at home on arch height. But this association has not been confirmed.

## CONCLUSION

From early childhood, it is important to take care to choose the right footwear, not to overload the foot arch, and at the same time not to try to support it artificially, to keep the weight in the normal range, to maintain overall good condition, and to try to compensate for sedentary work with other physical activity. In the studied sample of probands, there were also individuals with elevated BMI values, probands who used orthotic footwear even without a prescription, or who did not engage in any physical activity. However, the majority of the proband sample possessed a bilaterally normal arched foot, which is a positive result. Nowadays, there are a large number of orthotic devices on the market that help to shape the foot arch correctly, but it is not correct to use these devices arbitrarily, without a prescription and a doctor's diagnosis of foot arch deviation.

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**Conflicts of Interest**

None declared

**Adherence to Ethical Standards**

The study was approved by the Ethics Committee of Prešov University, Faculty of Humanities and Natural Sciences. All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards.

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